U.S. Department of Transportation
Federal Aviation Administration

Memorandum

Subject:	Action: Review and Concurrence, Equivalent Level of Safety Finding for Gulfstream Model GIV-X FAA Project Number No. AT5080AT-T	Date:	January 13, 2004
		Reg. Ref:	25.933(a)(1)(ii)
From:	Manager, Propulsion and Mechanical Systems, ANM-112	Reply to Attn of:	Carla J. Wendler ACE-115A
To:	Manager, Atlanta ACO, ACE-115 A	ELOS Memo #:	AT5080AT-T-P-1

Background

Gulfstream Aerospace Corporation (GAC) has updated the design of their GIV business jet aircraft to a derivative called the GIV-X, which includes new thrust reversers. GAC does not plan to show compliance with airworthiness requirement §25.933(a)(1)(ii) for the GIV-X, which states "The airplane is capable of continued flight and landing under any possible position of the thrust reverser." Rather than demonstrate compliance with the subject rule, Gulfstream has elected to show that the Model GIV-X thrust reverser design protects against in-flight reverser deployment to an extent that provides a level of safety equivalent to that provided by direct compliance with the rule.

Compliance with §25.933(a)(1)(ii) is intended to completely eliminate all risk of catastrophic in-flight reverser deployment from normal aircraft operation. Under §25.933(a)(1)(ii), any residual risk of catastrophic inflight reverser deployment would be limited to scenarios involving unusual aircraft configurations, abnormal flight conditions or inappropriate flight crew actions. Therefore, any design intended to provide an equivalent level of safety to the subject rule must limit the residual risk of catastrophic inflight reverser deployment to a similar level.

In general, the catastrophic risks from other aircraft system hazards are identified and managed through compliance with §25.1309(b)(1). Therefore compliance with this standard by the means delineated in the related AC25.1309-1A should be part of any equivalent safety finding utilizing probability that a catastrophic in-flight deployment will not occur. However, as documented in the docket justification for the subject §25.933 rule; “A review of the past operating history of airplane engine thrust reversers indicates that fail safe design features in the reverser systems do not always prevent unwanted deployment in flight. Many of these unwanted deployments are not caused by deficiencies in design but can be attributed to maintenance omissions, wear and

other factors that cannot be completely accounted for in the original design and over which the manufacturer generally has no control even when comprehensive maintenance programs are established." This perspective has been re-enforced by an AIA/FAA review of transport service history that indicated that many of the reverser in-flight deployment incidents involved inadequate maintenance or improper operations. Other factors such as uncontained engine failure, unanticipated system failure modes and effects and inadequate manufacturing quality have also played a role in service deployment incidents.

Therefore, in addition to the traditional reliability predictions provided in demonstrating compliance with §25.1309, any equivalent safety finding to §25.933 will require that the influences which could render that prediction invalid be identified and acceptable means for managing these influences be defined. To this end, compensating design assurance and continued airworthiness features must be provided for FAA Aircraft Certification approval which, as a minimum address:

1. Justification for any assumption made in the System Safety Analysis (SSA) including:
   (a) rationale for failure modes considered;
   (b) failure effects determination and verification methods;
   (c) criteria for assuring the completeness of any top down analysis (e.g. dependency diagrams, fault tree analysis (FTA), etc.);
   (d) rationale for failure rate data source applicability including consideration of relative design and manufacturing standards as well as the installation environment;
   (e) methods by which failures will be detected, isolated and eliminated prior to the assumed exposure times (e.g. exposure time may be justified by providing reference traceability to an FMEA that provides the resultant detection means, the MMEL or MRB documents that establish the detection interval, and the Trouble Shooting and/or Maintenance Procedures that set the effectiveness intervals required to isolate and eliminate the fault); and
   (f) verification of any fault independence assumptions (e.g. independence between all failure conditions contributing to any FTA "and gate").

When providing these justifications, the effects of other systems that have physical, zonal or functional interfaces with the reverser must be taken into account. (i.e. failures within the airplane hydraulics, ECS or electrical systems may be significant to the SSA. Also engine uncontained failure or fire may have a significant impact on the integrity of the thrust reverser and must be addressed.)

2) All applicable lessons learned from the collective fleet experience delineated in Appendix A of the "Criteria for Assessing Transport Turbojet Fleet Thrust Reverser System Safety" including:
   (a) providing protection from inadvertent crew actuation;
   (b) validating the accuracy and effectiveness of flight deck design and crew procedures as they relate to reverser operation and failure modes;
   (c) limiting reliance on use of aerodynamic means to keep the reverser stowed;
   (d) minimizing of and justification for any latent failures (this should include latency due

to faults which are "made latent" either due to loss of the detection means or due to the fault being intermittent);

(e) providing system contamination tolerance;

(f) validating maintainability, both in the design and procedure. This validation should include at least verification that the system and procedures that support the SSA assumption, are tolerant to anticipated human errors, and that any critical procedures are highlighted for consideration as required inspection items (e.g. if under some anticipated dispatch conditions an improperly performed reverser lock-out procedure could leave the reverser without any active restraint, depending on the potential for mis-maintenance). The GIV-X procedure may need to be independently witnessed by an approved inspector.)

(g) providing protection from common mode failure sources such as environmental conditions, uncontained engine failure, and fire.

3) Means to monitor and report in-service experience relative to thrust reverser system safety and effectively respond to any conditions which may invalidate this equivalent safety finding.

Applicable regulation(s)
§§25.933(a)(1)(ii) and 25.1309(b)(1)

Regulation(s) requiring an ELOS
§§25.933(a)(1)(ii) at Amendment 25-72

Description of compensating design features or alternative standards which allow the granting of the ELOS (including design changes, limitations or equipment need for equivalency)

Gulfstream has declared that that GAC Model GIV-X will not demonstrate compliance with the subject rule. Therefore Gulfstream must demonstrate that the GAC Model GIV-X is protected against catastrophic in-flight reverser deployment to an extent which provides a level of safety equivalent to that provided by direct compliance with the rule. This demonstration must include at least:

1) A rigorous qualitative safety analysis to show that no single failure or malfunction, regardless of the probability, can result in a catastrophic in-flight reverser deployment. In addition to the traditional Failure Modes and Effects Analysis (FMEA) a top down analysis, at least to the assembly level, should be performed to assure that any obscure single failure modes are identified.
2) An average risk analysis in accordance with AC25.1309-1A that predicts that catastrophic in-flight reverser deployment will not occur in the fleet life of the GAC Model GIV-X.
3) A specific risk analysis which predicts that at the beginning of each flight the aircraft will continue to meet the "no single failure" criteria of analysis #1 above and that the risk of catastrophic in-flight deployment is less than $1x10^{-6}$/flt. hr. This analysis is only required if the design can have contributory faults present for more than one flight. This analysis

must consider any aircraft configuration (including latent faults) anticipated to occur in the fleet life of the airplane type that is not proposed to be precluded from dispatch by the MMEL. For the purpose of this analysis a configuration whose probability of occurrence is greater than $1x10^{-8}$ must be assumed to occur unless a lower total fleet exposure time can be justified by prescribing either production or utilization limits. This analysis provides a previously unavailable tool to assist in the assessment of MMEL and MRB proposals.

4) Verification that the influences which could render these predictions invalid have been identified and acceptable means for managing these influences throughout the fleet life of the GAC Model GIV-X have been defined and implemented.

Explanation of how design features or alternative standards provide an equivalent level of safety to the level of safety intended by the regulation

Compliance with §25.933(a)(1)(ii) is intended to completely eliminate all risk of catastrophic in-flight reverser deployment from normal aircraft operation. Under §25.933(a)(1)(ii), any residual risk of catastrophic inflight reverser deployment would be limited to scenarios involving unusual aircraft configurations, abnormal flight conditions or inappropriate flight crew actions. By following the alternative standards noted above, Gulfstream has provided an equivalent level of safety to the subject rule by limiting the residual risk of catastrophic inflight reverser deployment to a similar level.

FAA approval and documentation of the ELOS

The FAA has approved the aforementioned Equivalent Level of Safety Finding for the GIV-X in Issue Paper P-1. This memorandum provides standardized documentation of the ELOS that is non-proprietary and can be made available to the public. The Transport Directorate has assigned a unique ELOS Memorandum number (see front page) to facilitate archiving and retrieval of this ELOS. This ELOS Memorandum number should be listed in the Type Certificate Data Sheet under the Certification Basis section (TC's & ATC's) or on page 3 of the STC Certificate. [E.g. Equivalent Safety Findings have been made for the following regulation(s): 25.933(a)(1)(ii) Reversing Systems, and 25.1309(b)(1) Equipment, Systems and Installation (documented in TAD ELOS Memo No. AT5080AT-T-P-1)].

Original signed by Neil D. Schalekamp 1/14/04

Manager, Propulsion and Mechanical Systems, ANM-112 Date

ELOS Originated by:	Program Manager:	Routing Symbol:

Atlanta ACO	Carla Wendler	ACE-115A